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FORTUNE

SPECIAL REPORT

THE HIGH-TECH RACE

Bell Labs breakthrough: Chips that work like the brain

WHO'S AHEAD NOW

Where the U.S. stands vs. Japan, Europe, and Russia on the Frontiers of Science

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OCTOBER 13, 1986 VOL. 114, NO. 8

FORTUNE

The wafer of silicon, photographed by Black Star's Kim Steele at Bell Laboratories in New Jersey, contains computer chips designed to mimic the way brain cells work. *See page 26.*

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THE HIGH-TECH RACE

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SPECIAL REPORT

THE HIGH TECH RACE
WHO'S AHEAD?

WHAT ACCOUNTS for the amazing surge in the U.S. standard of living since the end of World War II? Capital, abundant natural resources, and economies of scale in the world's largest developed market all contributed to the doubling of output per man-hour over the past 40 years. But the largest single factor has been the forward march of U.S. science and technology. A Brookings Institution study, for example, ascribes 44% of the increase in productivity to technological innovation. Other economists estimate that during the past two decades innovation has accounted for almost two-fifths of the growth in the U.S. GNP.

The power of American inventiveness—from the light bulb to the laser, from the tractor to the transistor—is legend. But now the rest of the world is determined to catch up. Leaders of diverse political persuasions, from Mikhail Gorbachev of the Soviet Union to Yasuhiro Nakasone of Japan, agree that accelerated scientific and technical progress holds the key to the future economic and even social well-being of their countries. As other nations build up their scientific and technical skills, American dominance of world science and technology is slipping. A cautionary straw in the wind: This year, for the first time, U.S. high-tech imports are expected to exceed high-tech exports.

The U.S. still outspends all other nations in civilian and military research and development combined, and it continues to serve as the world's principal science schoolhouse and R&D lab. The great U.S. idea factories, such as American Telephone & Telegraph's Bell Laboratories, and leading research universities, like Caltech, MIT, and Stanford, remain the world's major wellsprings of new knowledge. But foreign students now get more Ph.D.s at U.S. universities in physics, mathematics, and engineering than Americans do.

All of the non-Communist world faces a formidable adversary in the Soviet Union, whose scientific and technological capabilities are often underestimated. With increased freedom and more and better computers, the U.S.S.R. could well emerge as the surprise entry in the global high-tech sweepstakes. Moreover, the industrial democracies are battling murderously among themselves for markets. Those who lead in translating new technologies into products and processes will reap the rewards in competitive advantage. So any weakening of U.S. dominance could threaten the future prosperity and safety of Americans.

The following article in this special report examines how the U.S. ranks in the high-tech race vs. Japan, Western Europe, and the U.S.S.R., with scorecards based on interviews with more than 40 knowledgeable scholars and business executives. Then FORTUNE appraises what the U.S. can do to enhance its competitiveness, looks at what will be taking place on the frontiers of science between now and the year 2000, and profiles ten outstanding men and women from around the world who are making that future happen.

BY GENE BYLINSKY

WHERE THE

COMPUTERS, CHIPS, AND FACTORY AUTOMATION

IN THE HEADLONG RUSH of high technology, the driving force has been the computer and everything connected with it—semiconductor chips, robots, telecommunications. By the year 2000 the electronics industry, already a $300-billion-a-year business, should more than triple in sales to become the biggest in the world except for agriculture. The nation that dominates it will stand astride the world economy like a 21st-century Colossus.

American scientists at Bell Labs pioneered the modern electronics age with the invention of the transistor in 1947. Japan has put that breakthrough and subsequent discoveries to use in consumer products, but its strength has been efficient manufacturing rather than basic science. Western Europe has excelled in both the design and manufacture of advanced telecommunications systems. The Soviet Union lags as much as ten years behind the West in most fields of electronics. As the chart below indicates, experts consulted by FORTUNE award the U.S. the top rank by a substantial margin in computers, the biggest component of the industry.

Control of the computer market by American companies seems assured for the immediate future. IBM, with 60% of the industry's worldwide sales and perhaps as much as 70% of the operating profits, will be hard to dislodge. Western European computer manufacturers account for a mere 10% of worldwide sales, the Japanese another 15%. The Soviets do not sell computers in the West; their main preoccupation is catching up.

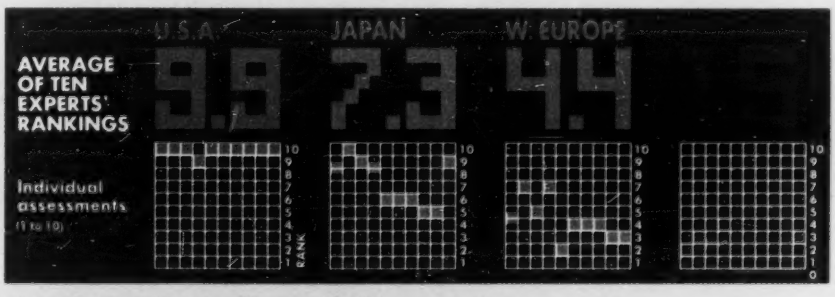
Because of the myriad strands that go into computerized electronics, however, it is not easy to predict how long U.S. dominance will continue. Semiconductor circuits—chips—are the No. 1 strand. They are the key to everything electronic, the innards of all sizes and shapes of computers as well as consumer electronic goods, where Japan's rule has begun to be challenged by South Korea and Taiwan. Until this year U.S. merchant chipmakers led the world in sales. According to the respected industry analysts at Integrated Circuit Engineering Corp. of Scottsdale, Arizona, Japan will vault to the top by the end of 1986. Three Japanese companies, NEC, Hitachi, and Fujitsu, will take over leadership from Motorola and Texas Instruments.

U.S. chipmakers still retain the lead in the design of microprocessors, which serve as the brains of electronic equipment like personal computers and engineering work stations. The U.S. has 43% of the $2.75-billion-a-year world market in microprocessors; Japan has 34%, and Western Europe 18%. Fred Zieber, senior vice president of Dataquest, a San Jose, California, firm that keeps track of electronics markets, says the U.S. is likely to dominate the high end of the microprocessor market for the foreseeable future. But U.S. companies are beginning to lose share to the Japanese in high-volume parts like Motorola's popular and widely used 68000 and 68020 microprocessors, which the Japanese make under license. "They don't have to innovate in microprocessor architecture," says Glen Madland, chairman of Integrated Circuit Engineering. "They can buy it fresh or used. We lose to the Japanese in production effectiveness." The Japanese make many other American microprocessors under license, often cheaper and of better quality than their U.S. inventors can.

Western European companies are leading in some important subdivisions of semiconductor technology. For example, ITT's European subsidiary, Standard Elektrik Lorenz, was the first to develop chips for digital processing of television pictures, which greatly improves image quality. West Germany's Siemens is the world's first supplier of a complete line of components for so-called integrated services digital networks, which allow data, voice, and video to travel over the same communications line. Jacques Ernest, technical director of Alcatel, the major French communications company, puts Western Europe and Japan ahead of the U.S. in the development of digital networks like Siemens's. Cie Générale d'Electricité, parent of Alcatel, agreed in August to buy the ITT subsidiaries in Europe for $1.5 billion. Eurotel, the new company, will be the second-largest telecommunications company in the world, behind only AT&T.

In a joint venture with Holland's Philips, Siemens is trying to produce an unusually large memory chip to keep Europe in the

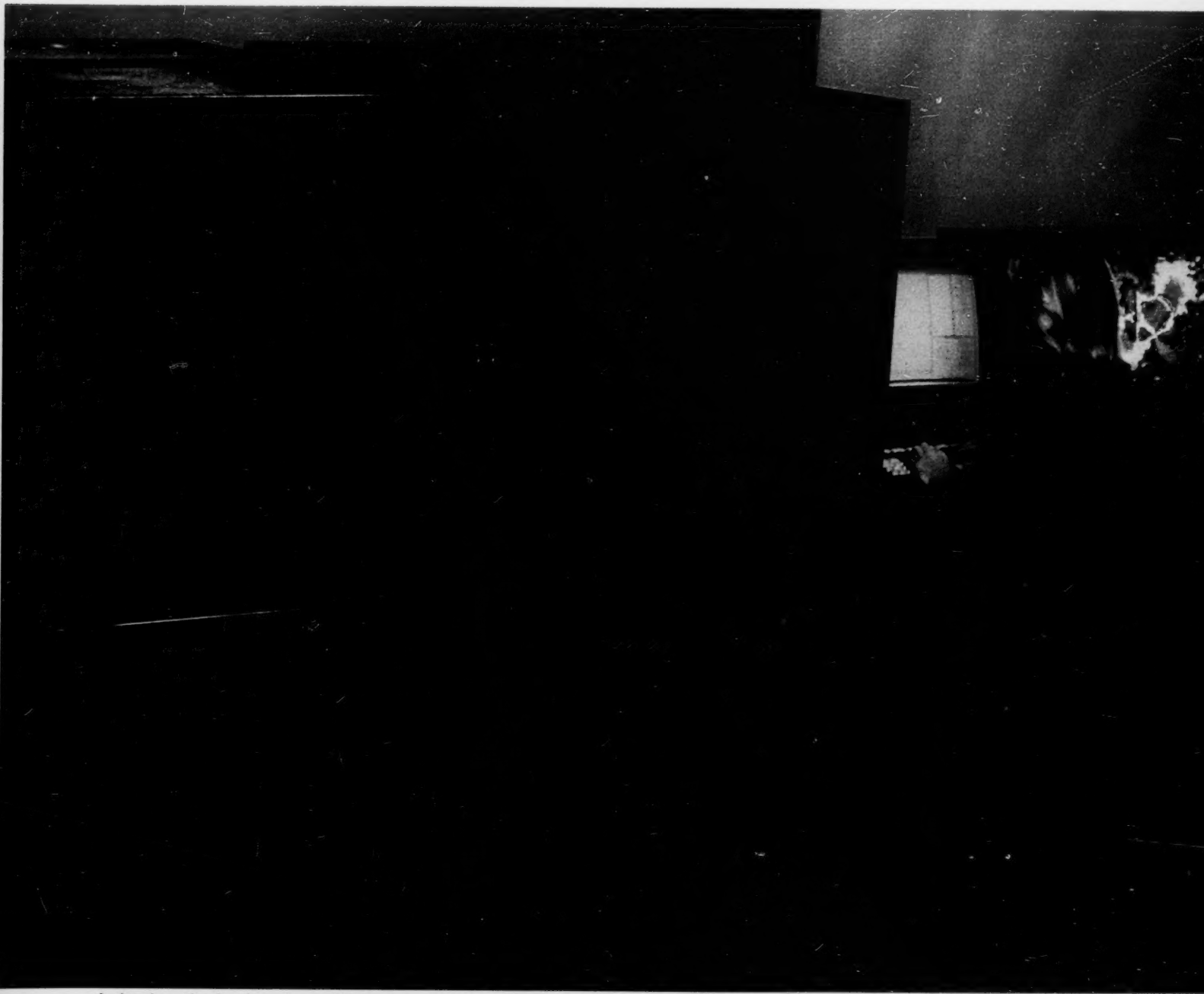
REPORTER ASSOCIATE *Alicia Hills Moore*



FORTUNE Scoreboard: Computers

This chart and the three on the following pages rate achievement in key areas of high technology. FORTUNE *asked ten scholars, business executives, government officials, and foundation leaders in each field to rank the state of research and development in the U.S., Japan, Western Europe, and the U.S.S.R. on a scale of 1 to 10.*

U.S. STANDS



Imitating the brain, *where millions of neurons work as a team, new computers like this Connection Machine use vast numbers of processors that function in parallel. They excel at complex tasks like modeling the fluid flow shown on the screen at right. The red lights help spot any bugs.*

PHOTOGRAPHS BY KIM STEELE—BLACK STAR

semiconductor race. Philips and Siemens are putting up about $400 million each, the Dutch and West German governments another $400 million. As of now, though, in mass-produced memory and microprocessor chips Western Europe lags behind both Japan and the U.S., with only 21% of the world market.

Aiming to dominate that market, the Japanese have won the first big battle. They now control 67% of the $1.65-billion-a-year world market for dynamic random-access memory (DRAM) chips. DRAMs are to computers and other electronic equipment what paper is to writers. They are the most widely used and cheapest memory chips. Because DRAMs are manufactured in huge quantities, they are also an excellent means for honing new processes and production techniques.

In a detailed study of the chip industry last December, Charles H. Ferguson, an MIT political scientist, concluded that the smaller U.S. companies cannot begin to compete with Japan's huge, powerful companies like NEC, Hitachi, and Fujitsu in increasingly complex chip structures and systems. The U.S. makers, however, will continue to get defense-related work like the VHSIC program for making superchips little more than an inch on a side that will be as powerful as some of today's supercomputers (FORTUNE, September 29).

The Japanese now lead the world in the development of gallium arsenide, a material with great promise for future computers and telecommunications networks because it can handle both electronic and light signals. Gallium arsenide chips can also process information almost ten times faster than silicon chips. IBM, AT&T, and a number of start-up U.S. companies such as Gigabit Logic and Vitesse Electronics, both in the Los Angeles area, are hard at work on gallium arsenide. The U.S. Department of Defense has a large program in the material, mainly for signal processing, at many aerospace companies. In Western Europe companies such as Thomson, Philips, and Plessy are doing gallium arsenide research. The Soviets also have some studies going.

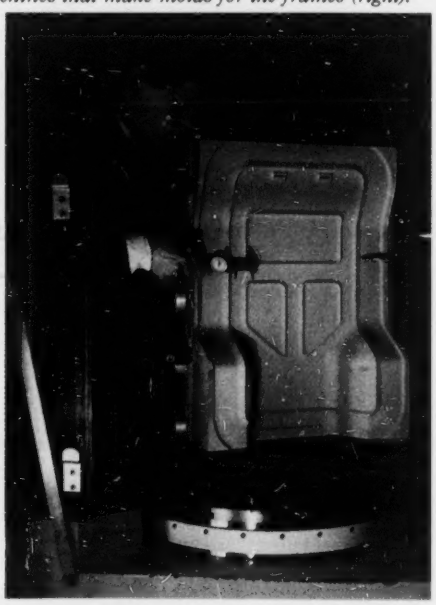
THE SCOPE, size, and intensity of the Japanese effort in the development of new technologies for chip manufacture invariably startle visitors from the West. The newest approaches to chipmaking include optical and X-ray lithography techniques that will allow the further drastic shrinkage of the dimensions of microminiaturized transistors and their related components. Work on these techniques at all the major Japanese electronics companies, including NEC, Hitachi, and Fujitsu, is now comparable in scope with that at IBM and AT&T's Bell Labs, long the leaders in chip technology.

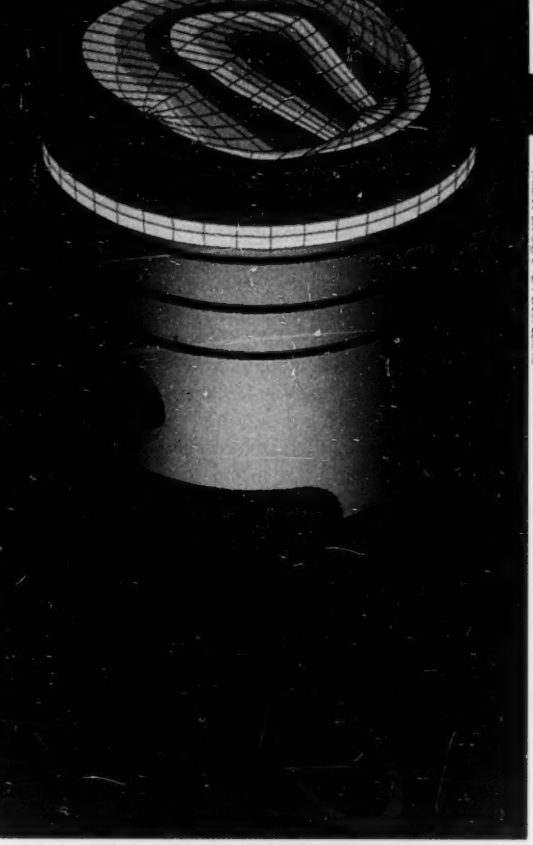
In computers, the enterprise of American start-up companies and IBM's formidable worldwide presence have so far prevented the Japanese from becoming threatening competitors. With their incessant innovations, the small U.S. entrepreneurial companies have kept their less adaptable Japanese rivals off balance. No easy targets like the DRAM chips have opened up. So the Japanese have been left with the unimaginative copycat approach, imitating IBM machines and software.

But a new stage is emerging in computing, and many scientists in the field wonder if the next step may not favor the Japanese. Warns Geoffrey Fox, a pioneering supercomputer designer at Caltech: "Now is the time Japan could just walk in and steal the baby." That next stage is parallel processing, a topic that necessarily recurs throughout this special report. Technically it involves a turn away from conventional step-by-step linear data processing to systems where a large number of processors—dozens, hundreds, even thousands—simultaneously attack a problem. Parallel processing would not only reduce the time required to retrieve and store data but also increase the complexity of the commercial and scientific tasks that a computer could tackle.

At the same time, parallel processing is the perfect vehicle for artificial intelligence (AI) because AI programs eat up so much computing power. The most completely developed form of AI takes the distilled skills of specialists and offers them as computerized "expert systems" to help the less adept—for example, by guiding a novice employee through the process of judging a customer's credit-worthiness. Parallel processing is

From art to part: *at GE's Schenectady, New York, R&D center, computers speed turning plans into products. At left, an engineer creates and tests a design for a plastic backpack frame; the computer automatically sends instructions to machines that make molds for the frames (right).*





PARAN DIVISION, PDA ENGINEERING

Time-saving software *from PDA Engineering in Irvine, California, can be used to detect and analyze hot spots in a piston (in color at top) without building a real-life model.*

made to order for supercomputers—the great new machines that allow such feats, crucial to industrial competitiveness, as testing an airplane's wing inside the computer with airflow simulated by an electronic "wind" consisting of equations and formulas. A recent National Science Board report says that ever faster supercomputers will allow researchers to simulate and display on monitor screens the creation of the universe, the unseen innards of stars, a thought slipping through a brain.

The big question about AI is who will take the lead—Japan or the U.S.? The other potential player, Western Europe, is still marshaling its forces. As in the rest of electronics, the Soviet Union lags far behind.

So far American entrepreneurial companies are leading in AI, supercomputers, and parallel processors for commercial applications. Teradata Corp. of Los Angeles, for instance, has just delivered to Citibank what may be the most powerful computer ever for business applications, a system that will eventually consist of 168 individual interconnected processors. Citibank will be able to get answers in minutes to complex questions that would take days, even weeks, on conventional computers—say, retrieving almost instantaneously such data as the names of all customers in the U.S. Northeast who earn more than $50,000 a year and have mortgage loans and checking accounts. This helps the bank target its marketing strategies more precisely. A large number of companies, including Inference Corp. of Los Angeles, Teknowledge of Palo Alto, California, and Symbolics of Cambridge, are beginning to supply expert systems packages for a wide range of industries.

What pleases AI doyens such as Edward A. Feigenbaum, a Stanford professor, is that bigger companies such as Texas Instruments and Control Data are also entering the field. Three years ago Feigenbaum coauthored a book that bitterly criticized large U.S. corporations for missing the AI bandwagon. But now he is happily surprised at how fast they are moving. IBM too is gearing up to enter the AI expert systems market soon. So far IBM has only a few high-end machines that offer a rudimentary form of parallel processing, but work on it is a major program at the Thomas J. Watson Research Center that towers like a green-glass battleship over the hills of New York's Westchester County. "We're very open-minded about the way we solve problems," says Ralph E. Gomory, a senior vice president and chief scientist at IBM. "If parallel processing turns out to be a terrific thing, I assure you that we are not going to ignore it."

Parallel processors come in two versions, sometimes combined in the same machine. In vector, or "lock step," processing, relatively simple arithmetic operations are performed simultaneously on a set of data. In more advanced concurrent processing, dozens, hundreds, or even thousands of individual processors work on different aspects of a problem at the same time, an approach suitable to such complex problems as modeling the performance of a chemical plant.

The vector machines are exemplified by supercomputers such as the Cray machines and Control Data's Cyber 205 series. The newer concurrent processors are typified by the Teradata system and by the Connection Machine, which in its first commercial version has 16,384 individual processors. Later models will have 65,536. Thinking Machines Corp. of Cambridge, Massachusetts, makes the machine (its inventor, Daniel Hillis, is profiled on page 56). In addition to these and other commercial ventures, the U.S. government supports research on new supercomputers at New York University, Cornell, and the University of Illinois, among other institutions.

Racing on a parallel track is Japan's Fifth Generation project, which aims to leapfrog the rest of the world in AI and parallel processing. The first commercial product to emerge from the Fifth Generation program is the personal sequential inference machine (PSI) made by Mitsubishi Electric, one of the participants in the project. Instead of merely adding up numbers, the PSI deals with logical inferences. It is a work station, a desktop computer intended for the development of expert systems. While U.S. computer specialists aren't impressed—they have already built more powerful work stations of this type in university research projects—they will be if the Japanese meet their goal of a tenfold boost of PSI power by next year. "That would give them a dramatic performance advantage," says University of California computer scientist David Patterson.

"If five years down the line the logical inference approach turns out to be very important for a segment of the market," adds Patterson, "the Japanese will have a huge head start because few or no American companies are taking that view of building computers." But the Japanese have still to prove that mass can top class—that their big national and corporate teams can do better than brilliant individuals and small groups in the U.S. If the next step in computing requires massive application of resources and manpower, as in the Fifth Generation project, only IBM will be in a position to compete.

EVEN IF the Fifth Generation project does not meet its ambitious goals, it will help Japan improve its software production, now a weakness. The U.S. lead in software remains strong, partly because designing software is creative work that lends itself well to the individualistic American approach. The Japanese have been handicapped by their relative lack of software-writing skills in microprocessors, for example, but they are trying to make up for the lag by training more people. The Fifth Generation project envisions instructing 10,000 engineers in the intricacies of software and AI by 1995.

The Japanese project has energized research in the U.S., Western Europe, and the Soviet Union on AI. The Soviets, in fact, have launched a fifth-generation project of their own called START at a consortium of computer institutes in Moscow, Novosibirsk, and Tallin. Soviet researchers are trying to build a massive parallel computer, code-named MARS. Sy Goodman, a professor of computer science at the University of Arizona who follows Soviet

computer developments, says that some prototypes may be operating but little else is known. Because of Soviet scientists' traditional strength in mathematics and logic, Goodman expects them to make significant contributions in AI.

At the workaday end of computer applications lies the factory floor. Some American specialists claim that the U.S. is ahead in the total integration of automated manufacturing systems, while the Japanese lead in simpler types of automation. But the Japanese have the better idea. Hriday Prasad, manager of industrial control systems at Ford Motor Co. and a frequent vistor to Japan, discovered that when Yamazaki Machinery Works Ltd. decided to automate its Minokamo plant, its engineers were asked to lay out all the parts of its products, and the 672 tools used to make them, on huge tables that occupied an area the size of a football field. The engineers were asked to mull over this layout for months to allow elimination of unneeded tools. In the end the engineers cut the number to 45.

"In the West," says Prasad, "the tendency in designing a new plant is to grab all the new technologies you can get hold of—databases, computers, machines, whatever it is. The Japanese think simplicity first and get those technologies only if needed. The big emphasis in Japan is on designing products for ease of manufacture." But Americans can sometimes beat the Japanese at that game. IBM redesigned the PC printer to make it simpler to produce and says it now turns out the printer less expensively than Epson, IBM's former Japanese supplier, could.

While factory automation proceeds at a nice clip at big U.S. companies like IBM and some smaller ones like Allen-Bradley, most U.S. industry is moving slowly if at all. Glen Allmendinger, president of Boston-based Harbor Research, which keeps track of factory automation, says that while thousands of U.S. companies are installing computerized factory automation equipment, only 100 to 150 are actively forming plantwide networks. The U.S., he adds, is also lagging behind Western Europe in factory automation. Allmendinger says the Soviet Union "is in the Dark Ages."

LIFE SCIENCES

WHEN SIR ROBIN Nicholson, until recently science adviser to Prime Minister Margaret Thatcher, gave a talk in the U.S. earlier this year, a manager of a West Coast biotechnology firm came up to complain that the British government wanted to sell off its Plant Breeding Institute in Cambridge, a top-ranking research center. The only known bidder so far is Britain's chemical giant, ICI. If PBI went to the private sector, the American said, his firm would lose one of its best sources of research information. "That's exactly what we had in mind," Nicholson replied. "We have to start thinking about the well-being of U.K. Inc."

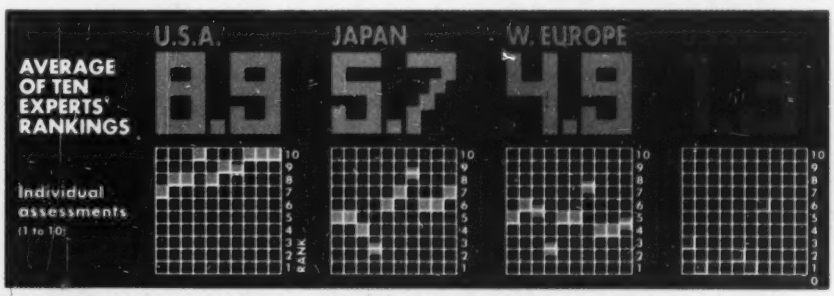
Such is the increasingly heated state of international competition today in biotechnology, the commercially promising product of the revolution in the life sciences that began with the 1953 discovery at Cambridge of the structure of DNA. The DNA molecule functions much like a perforated tape that tells factory machinery how to fashion a part out of metal or plastic. Genes in the threadlike DNA molecule are analogous to the coded instructions punched into the tape. They tell the cell machinery which proteins to make, which in turn determines the nature of the organism and how it develops.

Gradually scientists, principally in the U.S. but also in Western Europe, learned how to slice the tape and splice new segments of instruction into it. Now a common, harmless bacterium such as *E. coli* can be turned into a tiny factory by splicing a new gene into its DNA—for example, a gene that prescribes the making of a human growth hormone or human insulin that provides safer treatment for diabetics than insulin extracted from cows and pigs. The same type of genetic engineering can be applied to plants to improve their disease resistance or to sows to produce a sturdier piglet.

The commercial power of biotechnology is concentrated in genetic engineering, also known as recombinant DNA technology. But another booming biotechnology market has arisen from the discovery in England in 1975 of a way to make in the lab so-called monoclonal antibodies, proteins that unerringly seek out foreign cells—cancer cells, for example—which they lock on to as diagnostic markers or carriers of drugs designed to kill the invaders. Still another market: safer vaccines that mimic only a small part of the structure of a virus and for that reason are less likely than an ordinary vaccine to trigger a disease inadvertently. The body recognizes these vaccines and responds to them with the proper antibodies and other defensive substances, much as a detective would recognize a criminal by his fingerprints.

The knowledge that has made possible all this restructuring and remodeling of nature is being transferred with great efficiency from American and European universities to entrepreneurial biotechnology companies, the vast majority of them in the U.S. More than 200 American venture capital companies have jumped into the field. Already on the market are genetically engineered human growth hormone and insulin, both developed by Genentech Inc. of South San Francisco. Genentech is working on a number of other substances, such as tumor necrosis factor (TNF), which fights cancer, and tissue plasminogen activator (TPA), which dissolves blood clots.

Genentech's rival across the bay, Cetus Corp. of Emeryville, California, is turning out cancer-blasting Interleukin-2 for clinical trials and preparing a number of other immune system regulators for later marketing. Chiron Corp., across the street from Cetus, developed the first genetically engineered



FORTUNE Scoreboard: Biotechnology

The experts' rankings are for genetic engineering and other applications of the discoveries in molecular biology that have ensued since the structure of DNA was deciphered in 1953.

CETUS CORP.

Improving on nature, *Agracetus of Middleton, Wisconsin, is studying tobacco plants with a gene for resisting a disease. They are the first genetically engineered plants allowed out of the lab.*

vaccine—for hepatitis B, one of the principal forms of the dangerous liver disease. Merck Sharpe & Dohme will make and market the vaccine, which the FDA has just approved for general use. California Biotechnology Inc. of Mountain View is using recombinant DNA technology to make large quantities of human renin, an enzyme that regulates blood pressure.

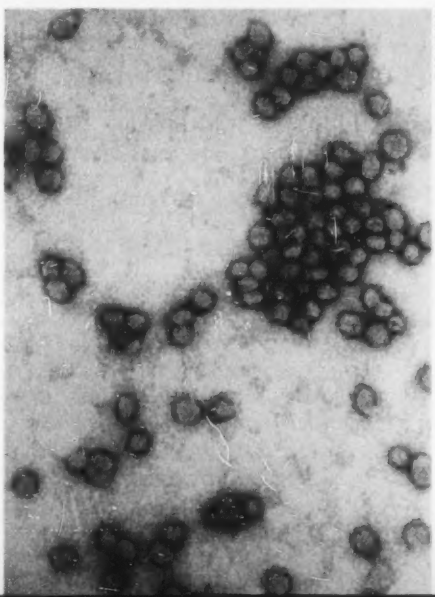
Both Genentech and Chiron are investigating the possibility of producing an AIDS vaccine. The companies' scientists have identified proteins on the surface of the virus particles—those telltale fingerprints. They reproduced those proteins in the lab and injected them into rodents, which produced antibodies to the AIDS proteins. The antibodies kill the virus in test tubes, but researchers have yet to establish that the vaccine would work in people.

Biotechnology is also big down on the farm. Agracetus of Middleton, Wisconsin, a joint venture of Cetus and W.R. Grace, is testing a tobacco plant with a disease-resistant gene; because of its ease of cultivation, tobacco is a convenient vehicle for trying out such genes for later use in food crops. Monsanto is preparing herbicide-resistant corn and wheat. Many other U.S. companies have genetic-engineering products in either laboratory testing or clinical trials.

The range and depth of U.S. activity in applications of genetic engineering is unmatched anywhere in the world—and so is the scope of life sciences research at American universities, national institutes, and private laboratories. According to the National Science Foundation, the U.S. probably spends about $10 billion a year on life sciences and biomedical research, more than all other nations combined. But rivals have not been exactly mesmerized. Japan is coming on especially strong, particularly in the practical aspects of biotechnology.

The Japanese are racing to strengthen their abilities in the life sciences because they believe that biotechnology will be a springboard that will vault Japan into the 21st century as world leader in technology. They have some way to go, to be sure. Japan is lagging in fundamental biology but it is trying to catch up, both by tapping U.S. resources and by encouraging research at home. At the National Institutes of Health in Bethesda, Maryland, the world's principal biomedical research center, 311 Japanese researchers are now in residence—more than from any other country. The U.S. is actually supporting much of their work: Three-quarters of them are on NIH fellowships, while the rest are funded by Japanese institutions. From 1980 to 1983 Japanese companies concluded an astonishing 188 collaborative agreements with small U.S. genetic-engineering companies. The American venture capital firms needed cash to survive; the Japanese needed knowledge to expand their industry.

Chiron Corp. researchers *made a vaccine against hepatitis B virus by genetically engineering these particles that simulate it.*



CHIRON CORP.

The U.S. Congressional Office of Technology Assessment (OTA) sees a formidable biotechnology challenge in the making from Japan because, for one thing, a large number of Japanese companies—more than 130—in a variety of industries are getting involved. Among them are chemical, food-processing, textile, and paper companies. The new entrants include chemical makers Sunstar and Hitachi Chemical, food processors Ajinomoto and Suntory, and textile and paper makers such as Toray Industries and Asahi Chemical. Japanese companies have many joint ventures among themselves, and they have been exploiting their ties with U.S. start-ups.

A typical example is Kirin Brewery Co.'s $24-million deal with Amgen Corp. of Thousand Oaks, California. Kirin contributed $12 million in cash; Amgen supplied $4 million in cash and $8 million worth of technology. A brewer for more than 100 years, Kirin began to diversify into life sciences only four years ago because its beer market was going flat. A U.S. brewer faced with a stagnating market might well have diversified into other beverages. Kirin, in typical Japanese fashion, is reaching out into high tech.

KIRIN had got interested in erythropoietin, EPO for short, a hormone that stimulates the formation of red blood cells and might be used to treat kidney disease. The company had been extracting EPO from urine, painstakingly and in tiny amounts. In 1983, in a major scientific coup, Amgen synthesized the EPO gene. Kirin offered Amgen its production skills and the collaboration of its researchers on other projects in exchange for the $12 million, for which it also got the Japanese rights to EPO. "Amgen's technology opened the road for us to mass-produce EPO," says Koichiro Aramaki, manager of Kirin's pharmaceutical department. EPO is still in clinical trials and has not yet been approved for use in either the U.S. or Japan.

Western Europe was a slow starter, but

major companies there are now vigorously pursuing pharmaceutical applications of biotechnology. OTA reports that, on average, European companies' biotechnology R&D budgets lag somewhat behind those of established U.S. companies and even some start-ups. But as biotechnology processes gain wider acceptance in the pharmaceutical industry, American firms can expect competition from companies such as Bayer AG and Hoechst in West Germany, Hoffmann-La Roche, Ciba-Geigy, and Sandoz in Switzerland, and Rhône Poulenc in France.

AT FIRST European companies' involvement in biotechnology consisted mainly of research contracts with universities and institutes. More recently, though, the large European firms have begun to pour big money into establishing in-house research and expanding their scientific work in the U.S. Overall, OTA places Europe further behind the U.S. in the applications of biotechnology to product-related research than in fundamental studies. But strong market-oriented efforts by major chemical companies in West Germany and by pharmaceutical houses in Switzerland and Britain are under way.

Western Europeans are already doing well in selected areas. For example, Celltech, a six-year-old British start-up, is the star among some two dozen British biotech companies born since 1980. It leads the world in the bulk production of monoclonal antibodies, the specialized protein molecules that are useful not only in diagnosing and treating disease but also in purifying genetically engineered drugs like interferon and identifying toxins in food. "We intend to keep that lead," says Gerald Fairtlough, Celltech's chief executive. Recently Celltech won the first license from the U.S. Food and Drug Administration for bulk production of monoclonal antibodies in America. That gives it a leg up in both Europe and the U.S. and may help it crack the Japanese market.

Elsewhere in Europe important work in plant research is in progress at the Max Planck Institutes in West Germany. The first fusion of cells from different plant species produced an improbable new plant called the pomato. It grew only minuscule potatoes below ground and equally puny tomatoes above, but cell fusion is still being pursued by researchers everywhere. The potential now seems to lie in fusing cells of related species, such as a wild tomato with domesticated one, to improve the qualities of an existing plant rather than creating brand-new ones. Scientists once talked of miracle plants like soybeans as tall as fir trees, but so far they have been unable to produce anything by fusing cells from entirely unrelated plants. (Tomatoes and potatoes are distant cousins.)

A number of older European companies operate in biotech niches. Two examples: Holland's Gist-Brocades, which specializes in enzyme technology that has industrial uses ranging from food processing to waste cleanup, and Denmark's Novo Industries, known worldwide as a dependable supplier of insulin and industrial enzymes.

Europe hasn't thrown much money at its biotech scientists. But consider the disadvantage Soviet biotechnologists face. They have to make up for decades lost during the hegemony of Stalin's favorite agronomist, Trofim Lysenko, who defied accepted genetics by arguing that plants and animals inherit traits acquired by their immediate forebears. Lysenko managed to undermine Soviet work in the life sciences, which had traditionally been strong, by dismissing genetics as a capitalist hoax. He had scientists who disagreed with him sent to Siberia. Now, however, the Soviets have an extremely active program that puts particular emphasis on meeting the country's agricultural needs. About two-thirds of the U.S.S.R.'s huge land mass is unusable for agriculture because of permafrost, poor soil, or capricious climate. One goal of Soviet agricultural research is to develop plants that will grow in hostile conditions. Faster-ripening plants that mature during short summers, hardier and more productive species, and improved nutritional content are among the aims of the country's genetic engineering.

Soviet scientists also have strong programs in basic molecular biology and in health-related biotechnology. Walter Gilbert, a Harvard molecular biologist, credits Andrei Mirzabekov, now director of the Institute of Molecular Biology in Moscow, with setting him on the path that led Gilbert to his Nobel Prize-winning work in rapid sequencing of DNA—determining the order in which its components occur.

According to MIT professor Alex Rich, the Soviets are doing fundamental research in a number of areas of biology. One of the most vigorous programs is at the Shemyakin Institute in Moscow, a place he describes as "rather large and lavish." There, for example, Vadim Ivanov is studying ionosphors—molecules that carry ions across cell membranes. Understanding how this process works could help biologists learn how cells maintain a stable environment. Each cell is like an encapsulated world, "a pinched-off piece of the ocean," Rich says. The Soviet research could help scientists learn how the cell membranes keep the crucial chemical balance necessary for proteins to thrive or allow antibiotics to punch through to zap bacteria. Similar efforts are under way in the U.S., but Rich says the work at Shemyakin is second to none.

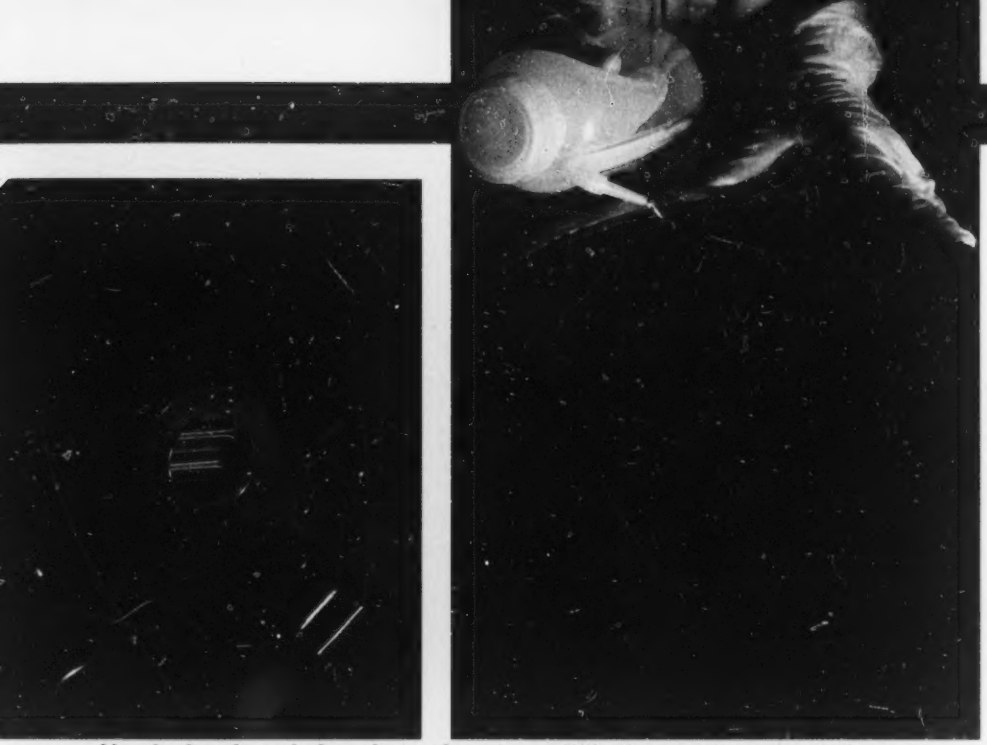
Other researchers at the institute are doing first-rate investigations of rhodopsin, the eye protein that transforms light into electrical impulses for the brain to process (see "What Tomorrow Holds"). That Shemyakin team is trying to unravel the chemical structure of the protein—an exceedingly difficult task, but one that could have a big payoff. "If we understand how rhodopsin operates, it could lead to understanding how vision works, which should help in correcting sight impairments," says Elkan Blout, a Harvard biochemistry professor.

ADVANCED MATERIALS

THE RISE OF CIVILIZATION has depended on the emergence of materials that gave their names to whole epochs—the Stone Age, the Bronze Age, the Iron Age. Yet however vital they were to man's march from the cave to the computer, until recently the materials involved have been mostly nature's gifts or simple improvements on them: sand melted into glass, ores purified into metals. But now the world stands on the threshold of a new age of *man-made* materials.

Today scientists can tailor the basic structures and properties of materials to suit their needs. Companies that lead in inventing and producing these ingredients of tomorrow will be in a strong position to dominate many high-technology industries.

A stream of new materials with remarkable qualities is already flowing from the labs: glass that bends without breaking, plastics as tough as steel, metals that stretch. Inside high-vacuum chambers, materials for electronic and optoelectronic applications—those that link electronic data processing with light-based data transmission through optical fibers, for example—can now be made in layers as thin as a single atom.



Newly developed phosphate glass *for amplifying lasers undergoes heat testing at the University of Rochester (left). It will be used for laser mirrors like the one being assembled at right.*

These optoelectronic circuits will start moving into the innards of computers and communications equipment in the near future.

This new technology is turning one of primitive man's first creations, ceramics, into materials with a vast range of applications, from artificial tooth implants to shielding for nuclear reactors. And the ability of modern science to cool molten metal almost instantaneously is yielding materials with new, improved electrical properties such as greater conductivity, while the capacity to bombard materials with ions—atoms stripped of some of their electrons—makes possible new semiconductor structures for use in electronics. Ralph E. Gomory, a senior vice president and chief scientist at IBM, thinks the development of new materials will set the pace of progress: "Every single step in computing has depended on solving one materials problem after another."

In materials research Western Europe and the Soviet Union are spotty performers. Most experts rank the U.S. as No. 1 in basic research, but Japan holds the lead in using science most effectively to produce new materials. The Japanese have launched a national drive to be first in developing materials for electronics and optoelectronics. Earlier this year a group of U.S. scientists from national laboratories and industry toured ten Japanese labs and came back with a disquieting report that was issued jointly by the National Academy of Sciences and the National Academy of Engineering.

The team found that within the past year the U.S. has lost leadership in seven out of nine critical emerging technologies in electronic and optoelectronic materials. The Americans were particularly impressed by the MITI Optoelectronics Joint Research Laboratory near Tokyo, directed by Izuo Hayashi, a world-acknowledged pioneer in the field (see page 55).

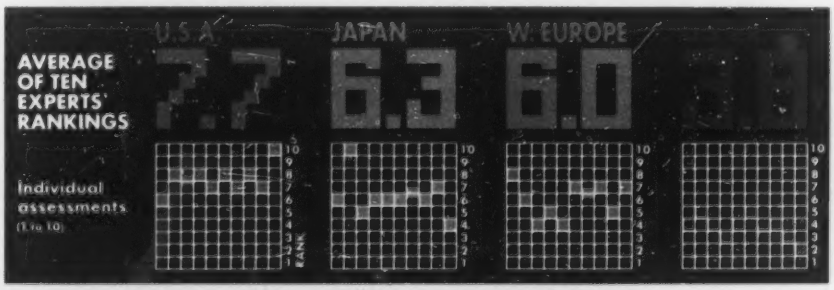
Hayashi and his team of 50 researchers have built a unique facility, an assemblage of interconnected high-vacuum chambers and processing machines that looks like a high-tech soup kitchen. There they are working to turn out new materials that are expected to be the building blocks of electronics seven to ten years from now. The Japanese are using what is called molecular beam epitaxy (MBE) to deposit finely controlled layers of material—a process invented at Bell Labs.

By FORTUNE's rankings, the Soviet Union comes in last in all four major areas of technology, but it does best in advanced materials, in part because of one remarkable discovery. The Soviets have found a way to deposit an ultrathin film of diamonds on the surface of materials to harden them and impart other qualities. For example, the heat that semiconductor chips generate can cause malfunctions if it is allowed to build up. The Soviet discovery makes it possible to dissipate that heat by conducting it though a thin diamond layer underneath the working part of the chip.

WHAT'S MORE, James Ionson, director of the Innovative Science and Technology office of the Star Wars project, suggests that a similar technique that U.S. researchers are now pursuing could "absolutely revolutionize" the semiconductor industry. He thinks that the thin diamond films themselves could be used to build chips that would be even faster than those made from gallium arsenide. Ionson's office is now supporting research on diamond coatings because they could be extremely useful in optical lenses and other components of Star Wars. More mundane applications could produce scratchproof glass and razor blades that hold their edge longer.

The scientist responsible for the discovery, Vladimir Deryagin of the Institute of Physical Chemistry in Moscow, began his pioneering research in the 1970s. His technique involves a low-pressure apparatus in which microwaves excite a mixture of methane and hydrogen. Scientists would normally expect the end result to be a layer of graphite, but a surprising chemical reaction deposited a diamond film instead.

While Deryagin published his first report ten years ago, the U.S. has been slow to pursue civilian uses of the technology. The Japanese have been wider awake. About 20



FORTUNE Scoreboard: New Materials

For these rankings the experts rated the four competitors on development of exotic materials that have been put to scientific or industrial use within the past ten years.

Japanese companies, including Sumitomo and Chawra-Denko, have already taken the Soviet discovery and are turning it into product applications that include thin transparent diamond coatings for eyeglasses and airplane windows. Sony is test-marketing a loudspeaker with an element coated with diamond film that reproduces sound with greatly increased fidelity. Says Rustum Roy, a Penn State physics professor: "The Japanese grabbed the science and made it into a technology." Except that this time it was a Soviet invention, not an American one.

U.S. companies appear to be doing a lot better in a number of other new materials. Allied-Signal, for instance, picked up a Caltech discovery called metallic glass more than 20 years ago and is now carrying it into commercial production. It's not glass in the ordinary sense; you can't see through it. It's actually a metal cooled so rapidly that it ends up with the amorphous structure that distinguishes glass from the highly ordered crystalline structure of metals. One of the properties of metallic glass is its ability to switch an electric current with little loss of energy. Allied makes the glass for transformers in the form of paper-thin ribbons that bend without breaking. Westinghouse and GE are evaluating prototype transformers that reduce the energy lost from switching by 75%, which could save U.S. consumers a billion dollars a year. Allied dominates the world market for the new glass, which Hitachi and TDK in Japan and Siemens Vacuumschmelze in West Germany are just entering. It has many other applications, such as joining metal parts in jet engines.

U.S. companies are strong in composites and polymers. Composites are materials such as ceramics and plastics that have been reinforced with synthetic fibers and carbon filaments. Alexander MacLachlan, Du Pont's senior vice president for technology, believes that composites will replace metals in some automobile and airplane parts to lighten weight and improve fuel efficiency. Polymers are plastics made of long molecules. They are now tough enough to replace steel in some applications and light enough to substitute for aluminum in others. GE is particularly strong in engineering plastics.

Polymers are also an area of Western European strength. One exciting development is the production of a biodegradable polymer using an unusual bacterium discovered by chance in a West German canal. Work on alternatives to oil-based bulk plastics began at Britain's ICI in the 1970s. By the early 1980s researchers could produce a few liters at a time of a new plastic, but stagnating oil prices made the market look uncertain. ICI persevered, setting up a subsidiary called Marlborough Bio-Polymer Ltd. that was partly financed with venture capital. Now, says John Adsetts, Marlborough's managing director, "we can produce tons of this stuff in a matter of days."

The bacterium is key to the process Marlborough uses to make the plastic; it produces something like 80% of its own weight as a polymer. Simply by changing the little fellow's diet—sugar, grain, or starch—Marlborough turns out a whole family of different plastics, "all unique and all patented," Adsetts says. Because the plastic, called Biopol, is biodegradable, it can be used instead of a bone plate; as the bone strengthens the plastic degrades, and no second operation to remove the plate is required. Adsetts sees a growing market as laws force consumers to turn increasingly to biodegradable plastics, and he thinks the Third World, often "sugar-rich but dollar-poor," is the ideal place to produce it. So far the Austrian chemicals maker Chemi-Linz is ICI's only competitor.

OPTOELECTRONICS

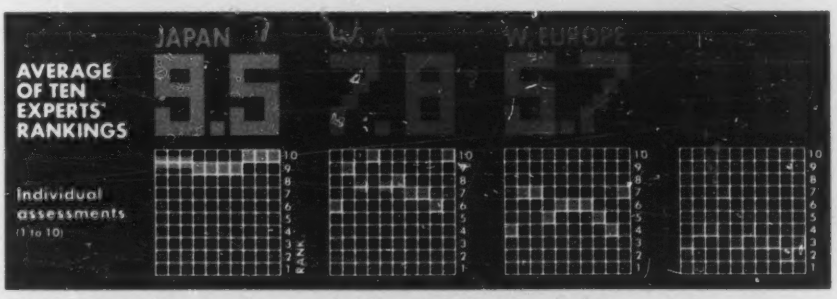
EVERYONE CONCEDES that the Japanese lead the world hands-down in one important new technology originally developed in the U.S. It is optoelectronics, a marriage of electronics and optics that is already yielding important commercial products such as optical fiber communications systems. Optoelectronics is widely expected to form the backbone of much of the next generation of information-based technology because it unites the electron with the ephemeral photon, the particle of light, to attain greater efficiency in data processing and transmission than electronics can achieve by itself.

So far it's the transmission side that has dominated the use of the photon. Photons can be employed as more compact carriers than electrons, transmitting massive amounts of data as laser pulses through hair-thin glass fibers. Optical communications networks are beginning to spread within and between cities around the world, replacing less efficient copper wires.

The next step: bringing optical switching and data transmission inside computers to speed up calculation. This will be achieved with chips that combine electronic data processing with photonic switching and transmission. Scientists in many countries are already experimenting with rudimentary chips of that sort. Integral to those systems—as well as to compact disks, automatic-focusing cameras, and many other consumer products—are semiconductor lasers no bigger than a grain of salt. They are made of semiconducting materials, in this case a variety of gallium arsenide.

Chips that allow photons to be switched may eventually lead to ultrafast computers that work entirely through optics, although most scientists are still skeptical. (Part of a Bell Labs optical computer project is shown in the photograph opposite.) Optoelectronics also includes such devices as light-emitting diodes used as displays in electronic calculators and other consumer and industrial products, and big lasers, not to be confused with their tiny semiconductor cousins.

The larger lasers, which represent an older technology, are used for a multitude of tasks, from determining the chemical compo-



FORTUNE Scoreboard: Optoelectronics

The rankings reflect progress toward combining light and electrons to make speedier computers. If the competitors were rated for laser research, the U.S. would be No. 1.

Lasers *at Bell Labs help in design studies for faster computers that use optics.*

sition of substances to cutting metal. FORTUNE's rankings do not include big lasers in the optoelectronics scoreboard. In big lasers Japan sinks to the bottom rank. The U.S. is No. 1, followed by the Soviet Union and Western Europe. In fact the larger lasers are one of the Soviets' few high-tech strengths besides diamond coatings. Back in the 1960s Nikolai Basov and Alexander Prokhorov of the Soviet Union shared the Nobel Prize as co-inventors of the laser with an American, Charles Townes.

But in the rest of optoelectronics, says Amnon Yariv, a pioneering researcher at Caltech, "the Japanese lead is very considerable. And there's little evidence that anything we are doing in this country will close the gap in the near future." Japan's commanding position in this rapidly developing field stems from a decision more than a decade ago by planners at the Ministry of International Trade and Industry (MITI), industrial scientists, and corporate executives to pour money and manpower jointly into the field. Since then at each of about ten major Japanese companies, including Hitachi, NEC, Fujitsu, and Mitsubishi, teams of up to 100 scientists and engineers have been working on optoelectronics, emphasizing the practical implementation of the new technology.

University and corporate researchers in the U.S. got into semiconductor lasers earlier, but stuck doggedly to innovation, conceiving and demonstrating most of the major building blocks of the new technology. The semiconductor laser was invented at GE, IBM, and MIT in the early 1960s and further evolved at Bell Labs. Corning Glass developed the first efficient optical fiber in 1970. A related technology, integrated optoelectronics, which combines data-processing electronics and semiconductor lasers on a single chip, was conceived and initially developed by Yariv and his co-workers at Caltech.

The lead slipped away not because the U.S. lacks theoretical knowledge in physics and optics. In fact, while the Japanese are now beginning to make first-rate theoretical contributions, the U.S. still shines in those fields. It is far ahead in fundamental optics, according to James Merz, a professor at the University of California at Santa Barbara and a former Bell Labs researcher who recently spent four months working at MITI's Joint Optoelectronics Laboratory near Tokyo. What's missing in the U.S. are size, direction, and sustained effort.

In optoelectronics, only Bell Labs mounts an effort that matches what a single Japanese company like Hitachi is doing. "The trouble is that the Japanese have ten Bell Labs," Merz says. In keeping with its reputation for pioneering, Bell Labs is doing excellent scientific work across the range of optoelectronics. For example, it recently built the first optical counterpart of the transistor, which its scientists hope will bring closer the day of the optical computer. Such a computer would be of particular value to AT&T. Because it can operate 1,000 times faster than an electronic computer, it would make a nearly ideal telephone switching system. Paradoxically, AT&T, whose Bell Labs was one of the developers of semiconductor lasers, is buying them from Hitachi for its transatlantic cable.

All told, the U.S. may have more researchers in optoelectronics than Japan does, but for the most part they are scattered in tiny groups doing defense-related work, with only secondary fallout for civilian industry. None of the teams is as production-oriented as the Japanese. Merz directs his university's recently formed Compound Semiconductor Center, supported in part by the Defense Department. By year-end he expects to have eight part-time researchers on his staff, which he considers "a good-size effort." The MITI lab where he worked has 50.

Western Europe and the Soviet Union suffer from a similar fragmentation. They have a few outstanding centers that specialize in optoelectronics, and little thrust toward harnessing the photon to a production technology. There are notable exceptions. A worldwide race is on to produce the purest possible glass fibers, and the French in particular are strong contenders. French researchers at the University of Rennes discovered what has become known as fluorine glass in 1974. The discovery was something of an accident: The team stumbled on it while trying to crystallize another substance. "Our big coup was not to throw the new fiber into the wastebasket," says Gwenhael Maze, president of La Verre Fluor SA, and a member of the discovery team. "Instead we kept analyzing and studying it."

Fluorine glass turned out to be sensitive to a far wider range of wavelengths than existing fibers, so it can carry more information. As Maze puts it: "Fluorine glass has a bigger optical window." The new glass has two applications. Maze's company is working on short-distance cables for medical and industrial uses. By running a cable from the mouth of a hospitalized patient to a measuring device, for instance, doctors can monitor the gases in the patient's breath and thus closely follow changes in his condition. The cable can distinguish the type of gas by the amount of heat it absorbs. The long-range use of the new fiber would be for telecommunications over vast distances with far fewer signal-boosting repeaters than are needed now. Some experts have speculated that transoceanic cables made of fluorine glass fibers might require no repeaters at all. But fluorine glass must be greatly purified and improved before it can be used for that purpose. Everyone is interested—from AT&T and Britain's Plessy to Japan's NTT.

HOLLAND'S PHILIPS HAS a head start in erasable optical storage disks that could one day replace the memory chips, magnetic tape, floppy disks, and hard disks that computers now use. The new disks have a seemingly boundless capacity for data, which can be recorded, read, and erased as needed by microminiaturized lasers. In the home entertainment market the optical disks will also be crowding in on compact disks, which Philips likewise pioneered. Unlike the optical disks, CDs cannot be erased; with optical disks, consumers will be able to record music from the radio or any other source. Says John Marcum, a former White House science adviser now at OECD in Paris: "Compared with optical storage disks, compact disks are as primitive as 78 rpm records."

YOUR COMING STATE TAX HIKE

Reform will push state income taxes up and eat into savings from the federal cut. Some people's total bill—federal, state, and local—will rise. Investors get hit hardest. ■ *by Ann Reilly Dowd*

WITH THE much ballyhooed tax bill about to pass, many people are focusing on how much they will save on federal taxes. If you are one of them, watch out: You may be about to get blindsided. Tax reform will also affect state income taxes, mostly for the worse. For most people, state tax increases will eat away only part of the savings from the federal tax cut. But for many others the state burden will grow so much that they will wind up paying more in *total* taxes—federal, state, and local combined—than they do now. That's the case in 19 states and the District of Columbia for a typical family of four with $60,000 a year in income.

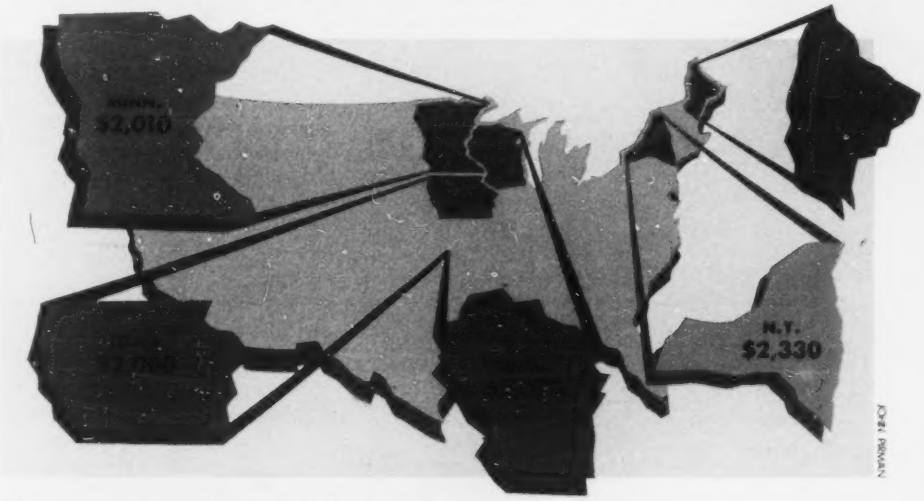
This is just one of the striking conclusions drawn from a FORTUNE analysis of how tax reform will affect state and local taxes. The study, the first to examine the impact of tax reform in all 50 states and the District of Columbia, was prepared for FORTUNE by Arthur Andersen & Co. The accounting firm calculated the taxes two hypothetical families of four would pay in 1985 and 1988, after the new federal law is fully effective. One family has $60,000 in annual income, the other $120,000. Arthur Andersen calculated state and local income, sales, real estate and personal property taxes. It did not consider most local income taxes, so the tax burden is understated in such places as New York City (for the effect of reform on your state and local taxes, see table on the following pages).

Some other findings from the study:

▶ The state with the highest tax bite remains New York and the lowest Alaska. In New York, the $120,000 family's taxes climb from $16,330 to $17,240; in Alaska they remain unchanged at $2,240.

▶ Tax reform will really sock it to investors. The $60,000 family's state tax rate on capital gains will shoot from 5.5% to 13.8% in New York and from 2.8% to 7.5% in Montana.

REPORTER ASSOCIATE *Lucretia Marmon*



Where the Bite Will Be Biggest

For a family with a $120,000-a-year income, reform will boost state and local taxes by more than $2,000 in these five states. The cost is net of savings from deducting state taxes on federal returns.

▶ People will probably look more closely than ever at state and local taxes in deciding where to live, and companies will do the same in considering where to build a new office. For example, the *difference* between the federal, state, and local taxes that the $120,000 family pays in New York and Vermont rises by more than $2,000 a year, to $7,900.

Federal tax reform only affects income taxes, but most of them will go up. That is because 34 states and the District of Columbia tie their income taxes to the federal system; their residents will lose many deductions and income adjustments on their state taxes that Congress is taking away at the federal level. In 14 of those states, taxes also climb because residents get to deduct federal income taxes on their state returns; as federal taxes decline that state deduction will shrink. Finally, residents of most states will pay higher capital gains taxes.

State and local taxes will remain unchanged in the nine states that do not have income taxes and in three states whose income taxes are not linked to the federal code. And taxes will drop in four states: Rhode Island, Vermont, Nebraska, and North Dakota. Their income taxes are a percentage of federal tax liability, so lower federal taxes will mean lower state taxes.

However, the true cost of state and local taxes will rise in all 51 jurisdictions for both the $60,000 and $120,000 families. The true cost is the amount of state and local taxes a family pays minus what it saves by deducting them on its federal tax return. That is the best way to measure the burden of state and local taxes because it is the amount of spendable income that taxpayers lose.

This cost of state and local taxes will rise everywhere because the federal savings from deducting them will drop substantially. Sales taxes will not be deductible at all, and lower federal tax rates will reduce the value of deducting income and property taxes.

On average, the cost of state and local taxes for the $60,000 family will rise $531, or 19%. The cost for the $120,000 family jumps an average of $1,305, or 25%, and goes up by $2,000 or more in the five states shown on the map. Says Stephen Corrick, a tax partner with Arthur Andersen: "Tax reform peels back the camouflage that has disguised the real cost of state and local taxes." Some governors have been promising to give back the windfalls they get from higher income taxes. But since no one really knows what the states will do, FORTUNE had Arthur Andersen base its calculations on present tax laws.

Both families in the study get hit hardest if they live in high-tax states that peg income taxes to the federal tax base. They fare best in low-tax states, especially those with low sales taxes. But some of the largest *percentage* increases in the tax burden will come in low-tax states. Even taxpayers in states without an income tax can get skinned. In Wyoming, for example, the net cost of the $60,000 family's state and local taxes rises 25%. The $120,000 family's net taxes go up 33%. But have no pity: In both cases the taxes will still be lower than everywhere else except Alaska.

The most punishing tax increases fall on capital gains. The federal government currently taxes only 40% of the gain on assets held more than six months, so that the top capital gains rate is 20%. Under tax reform, the federal government will tax the entire gain at the same rate as ordinary income. The top rate will be 28% in 1988, but families with taxable incomes above $71,900 will pay a 5% surtax to eliminate the savings from personal exemptions and the 15% rate on their first dollars of taxable income. For a family of four, the surtax applies to taxable income up to $192,930. Within that range, the top rate will really be 33%.

OF THE 42 STATES that tax capital gains, 31 apply their tax to the figure reported on federal returns, now 40% of the gain. Under tax reform, those states will automatically levy their tax on the full gain unless they change their laws. In other words, their capital gains taxes will rise by 150% or more. The com-

How Reform Affects Two Families' State and Local Taxes

	$60,000 FAMILY INCOME						$120,000 FAMILY INCOME					
	STATE AND LOCAL TAXES		MARGINAL STATE INCOME TAX RATE		MARGINAL STATE CAPITAL GAINS RATE		STATE AND LOCAL TAXES		MARGINAL STATE INCOME TAX RATE		MARGINAL STATE CAPITAL GAINS RATE	
STATE	1985	1988	1985	1988	1985	1988	1985	1988	1985	1988	1985	1988
Alabama	$1,990	**$2,370**	2.3%	**2.6%**	2.3%	**2.6%**	$3,180	**$4,110**	1.7%	**2.3%**	1.7%	**2.3%**
Alaska	$650	**$690**	0.0%	**0.0%**	0.0%	**0.0%**	$1,300	**$1,500**	0.0%	**0.0%**	0.0%	**0.0%**
Arizona	$2,250	**$3,000**	3.4%	**3.9%**	1.4%	**3.9%**	$4,150	**$5,620**	2.6%	**3.4%**	1.0%	**3.4%**
Arkansas	$3,500	**$4,010**	4.7%	**5.0%**	4.7%	**5.0%**	$6,240	**$7,600**	4.1%	**4.7%**	4.1%	**4.7%**
California	$3,120	**$3,650**	7.4%	**7.9%**	7.4%	**7.9%**	$6,860	**$8,380**	6.4%	**7.4%**	6.4%	**7.4%**
Colorado	$2,500	**$3,100**	3.7%	**4.3%**	1.5%	**4.3%**	$4,270	**$5,640**	2.9%	**3.7%**	1.1%	**3.7%**
Connecticut	$2,430	**$3,080**	0.0%	**0.0%**	1.9%	**5.0%**	$4,370	**$5,580**	0.0%	**0.0%**	1.6%	**4.7%**
Delaware	$2,620	**$3,150**	6.6%	**7.7%**	2.7%	**7.7%**	$5,130	**$6,450**	6.2%	**7.2%**	2.5%	**7.2%**
District of Columbia	$3,750	**$4,630**	7.4%	**7.9%**	3.0%	**7.9%**	$6,800	**$8,730**	6.4%	**7.4%**	2.6%	**7.4%**
Florida	$1,250	**$1,510**	0.0%	**0.0%**	0.0%	**0.0%**	$2,110	**$2,720**	0.0%	**0.0%**	0.0%	**0.0%**
Georgia	$3,180	**$3,640**	4.0%	**4.3%**	4.0%	**4.3%**	$5,750	**$6,980**	3.5%	**4.0%**	3.5%	**4.0%**
Hawaii	$2,990	**$3,910**	6.1%	**6.6%**	2.4%	**6.6%**	$5,480	**$7,230**	5.8%	**6.6%**	2.3%	**6.6%**
Idaho	$3,090	**$3,880**	5.0%	**5.4%**	2.0%	**5.4%**	$5,460	**$7,190**	4.4%	**5.0%**	1.7%	**5.0%**
Illinois	$3,030	**$3,460**	1.7%	**1.8%**	1.7%	**1.8%**	$5,430	**$6,640**	1.5%	**1.7%**	1.5%	**1.7%**
Indiana	$2,890	**$3,400**	2.0%	**2.2%**	0.8%	**2.2%**	$5,330	**$6,560**	1.7%	**2.0%**	0.7%	**2.0%**
Iowa	$3,560	**$4,470**	5.2%	**6.0%**	2.1%	**6.0%**	$6,100	**$8,100**	4.4%	**5.7%**	1.8%	**5.7%**
Kansas	$2,780	**$3,550**	3.5%	**4.0%**	1.4%	**4.0%**	$5,290	**$7,190**	3.0%	**4.2%**	1.2%	**4.2%**
Kentucky	$2,700	**$3,130**	2.8%	**3.2%**	2.8%	**3.2%**	$4,580	**$5,730**	2.1%	**2.8%**	2.1%	**2.8%**
Louisiana	$1,060	**$1,380**	1.8%	**2.0%**	0.7%	**2.0%**	$1,720	**$2,490**	1.3%	**1.8%**	0.5%	**1.8%**
Maine	$3,310	**$4,190**	6.1%	**6.6%**	2.5%	**6.6%**	$6,820	**$8,880**	5.8%	**6.7%**	2.3%	**6.7%**
Maryland	$3,450	**$4,210**	5.0%	**5.4%**	2.0%	**5.4%**	$6,140	**$7,730**	4.4%	**5.0%**	1.7%	**5.0%**
Massachusetts	$4,320	**$4,730**	3.6%	**3.9%**	7.2%	**7.8%**	$7,510	**$8,830**	3.1%	**3.6%**	6.2%	**7.2%**
Michigan	$4,900	**$5,600**	3.8%	**3.8%**	1.5%	**3.8%**	$9,390	**$11,290**	3.1%	**3.6%**	1.2%	**3.6%**

The table shows the impact of tax reform on the state and local taxes of two families of four. Arthur Andersen & Co. computed taxes and marginal tax rates (the rates on the last dollar of income) for 1985 and 1988, when federal rate reductions will be fully effective. The entries represent the out-of-pocket costs of state and local taxes—the taxes and rates the families pay minus what they save by deducting state and local taxes on their federal returns. The family with $60,000 of income has one earner with a $50,000 salary and $10,000 of capital gains; the $120,000 family has two earners—one making $75,000, the other $35,000—and the same $10,000 capital gain. Neither family has any tax shelters or consumer interest deductions. Both claim average sales-tax, miscellaneous, and charitable deductions for their income.

bined federal and state taxes on capital gains for the two families in the FORTUNE study would double in more than three-quarters of the states and the District of Columbia.

If the $120,000 family lives in Iowa, its capital gains rate—net of the savings from deducting that tax on its federal return—rises from 1.8% to 5.7%. The family's combined federal and state tax on capital gains zooms from 18.6% to 38.7%. In Delaware, the net capital gains rate for the $60,000 family goes from 2.7% to 7.7%; the combined federal and state gains tax goes from 15.9% to 35.7%. More than ever, the best states for investors are those with no tax on capital gains: Alaska, Florida, Nevada, New Hampshire, South Dakota, Tennessee, Texas, Washington, and Wyoming.

How will the states cope with the effects of federal tax reform? The four where income taxes will fall are already working on adjustments to recoup the lost revenue. Some politicians who expect a revenue windfall say they intend to keep some or all of the money. These include Montana Governor Ted Schwinden, Mayor Marion Barry of the District of Columbia, and gubernatorial candidates in Iowa, Virginia, and Wisconsin. And experts see more takers in the wings. Says Harold A. Hovey, editor of a newsletter called *State Budget and Tax News*: "Look for substantial interest in keeping the additional money in states with fiscal problems, like Alabama, Arkansas, New Mexico, Mississippi, Iowa, Louisiana, and Oklahoma."

The governors of New York, Michigan, Ohio, California, and Minnesota all pledge to cut taxes enough to offset their windfalls. But state legislators are talking about "reforms" that will leave high-income families paying more than they do now and others paying less. And don't look to the statehouse for capital gains relief. Says Raymond Scheppach, executive director of the National Governors Association: "Most states will go along with the federal government's new treatment of capital gains. It's too complicated to do otherwise." One thing, at least, seems certain. As Hovey puts it, "Next year will be the hottest in state tax policy in the decade." F

	$60,000 FAMILY INCOME						$120,000 FAMILY INCOME					
	STATE AND LOCAL TAXES		MARGINAL STATE INCOME TAX RATE		MARGINAL STATE CAPITAL GAINS RATE		STATE AND LOCAL TAXES		MARGINAL STATE INCOME TAX RATE		MARGINAL STATE CAPITAL GAINS RATE	
STATE	1985	**1988**	1985	**1988**	1985	**1988**	1985	**1988**	1985	**1988**	1985	**1988**
Minnesota	$3,460	**$4,350**	6.6%	**7.1%**	2.7%	**7.1%**	$6,580	**$8,590**	5.2%	**6.6%**	2.1%	**6.6%**
Mississippi	$2,600	**$3,130**	3.2%	**3.4%**	3.2%	**3.4%**	$4,800	**$6,050**	2.8%	**3.2%**	2.8%	**3.2%**
Missouri	$2,670	**$3,320**	2.8%	**3.2%**	1.1%	**3.2%**	$4,650	**$6,220**	2.1%	**2.8%**	0.8%	**2.8%**
Montana	$2,630	**$3,210**	4.7%	**5.4%**	1.9%	**5.4%**	$4,880	**$6,360**	3.6%	**4.7%**	1.4%	**4.7%**
Nebraska	$3,580	**$3,940**	4.2%	**3.8%**	1.7%	**3.8%**	$7,410	**$8,480**	4.5%	**4.2%**	1.8%	**4.2%**
Nevada	$1,020	**$1,260**	0.0%	**0.0%**	0.0%	**0.0%**	$1,720	**$2,240**	0.0%	**0.0%**	0.0%	**0.0%**
New Hampshire	$2,090	**$2,240**	0.0%	**0.0%**	0.0%	**0.0%**	$4,200	**$4,850**	0.0%	**0.0%**	0.0%	**0.0%**
New Jersey	$3,860	**$4,280**	2.4%	**2.5%**	2.4%	**2.5%**	$7,690	**$9,090**	2.0%	**2.4%**	2.0%	**2.4%**
New Mexico	$1,940	**$2,290**	3.6%	**3.8%**	1.4%	**3.8%**	$4,090	**$5,250**	3.8%	**4.3%**	1.5%	**4.3%**
New York	$5,120	**$6,000**	7.2%	**7.2%**	4.0%	**9.9%**	$9,470	**$11,800**	5.8%	**7.2%**	3.2%	**9.9%**
North Carolina	$3,390	**$3,870**	4.7%	**5.0%**	4.7%	**5.0%**	$6,030	**$7,340**	4.1%	**4.7%**	4.1%	**4.7%**
North Dakota	$2,120	**$2,380**	2.2%	**2.1%**	0.9%	**2.0%**	$4,250	**$4,930**	2.5%	**2.2%**	1.0%	**2.2%**
Ohio	$2,920	**$3,570**	4.2%	**4.6%**	1.7%	**4.6%**	$6,140	**$7,870**	5.2%	**6.1%**	2.1%	**6.1%**
Oklahoma	$2,440	**$2,930**	3.8%	**4.1%**	1.5%	**4.1%**	$4,520	**$5,880**	3.3%	**3.8%**	1.3%	**3.8%**
Oregon	$3,940	**$4,720**	4.7%	**5.4%**	2.1%	**5.4%**	$7,910	**$9,620**	5.8%	**6.7%**	2.5%	**6.7%**
Pennsylvania	$2,800	**$3,130**	1.6%	**1.7%**	1.6%	**1.7%**	$5,100	**$6,090**	1.4%	**1.6%**	1.4%	**1.6%**
Rhode Island	$3,750	**$4,150**	4.8%	**4.4%**	1.9%	**4.4%**	$7,700	**$8,810**	5.1%	**4.8%**	2.1%	**4.8%**
South Carolina	$3,090	**$3,530**	4.4%	**4.7%**	1.8%	**4.7%**	$5,480	**$6,840**	3.8%	**4.4%**	1.5%	**4.4%**
South Dakota	$2,110	**$2,450**	0.0%	**0.0%**	0.0%	**0.0%**	$3,840	**$4,730**	0.0%	**0.0%**	0.0%	**0.0%**
Tennessee	$1,540	**$1,870**	0.0%	**0.0%**	0.0%	**0.0%**	$2,610	**$3,370**	0.0%	**0.0%**	0.0%	**0.0%**
Texas	$1,660	**$1,920**	0.0%	**0.0%**	0.0%	**0.0%**	$3,070	**$3,750**	0.0%	**0.0%**	0.0%	**0.0%**
Utah	$3,080	**$3,960**	3.6%	**4.1%**	1.4%	**4.1%**	$5,200	**$7,110**	2.8%	**3.6%**	1.1%	**3.6%**
Vermont	$1,660	**$1,810**	5.4%	**5.0%**	2.2%	**5.0%**	$3,640	**$3,900**	5.8%	**5.4%**	2.3%	**5.4%**
Virginia	$3,010	**$3,620**	3.9%	**4.1%**	1.5%	**4.1%**	$5,390	**$6,800**	3.3%	**3.9%**	1.3%	**3.9%**
Washington	$1,540	**$1,880**	0.0%	**0.0%**	0.0%	**0.0%**	$2,660	**$3,410**	0.0%	**0.0%**	0.0%	**0.0%**
West Virginia	$2,350	**$3,170**	5.0%	**6.6%**	2.0%	**6.6%**	$5,860	**$7,790**	7.3%	**8.6%**	2.9%	**8.6%**
Wisconsin	$4,680	**$5,510**	6.8%	**6.8%**	2.7%	**6.8%**	$8,490	**$10,560**	5.5%	**6.7%**	2.2%	**6.7%**
Wyoming	$840	**$1,050**	0.0%	**0.0%**	0.0%	**0.0%**	$1,350	**$1,800**	0.0%	**0.0%**	0.0%	**0.0%**